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Seroprevalence of Measles and Mumps Antibodies among Medical and Paramedical Students at An-Najha National University, Palestine (2020-2021)

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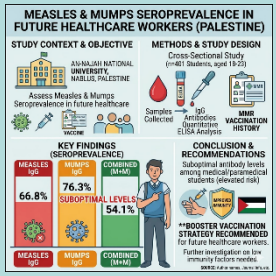
Abstract: Objective: This study assessed measles and mumps seroprevalence among medical and paramedical students at An-Najah National University, Nablus, Palestine, a group at elevated occupational risk. **Methods:** In this cross-sectional study, serum samples from 401 students (aged 18-23 years) were analyzed for measles-specific and mumps-specific IgG antibodies using quantitative ELISA. Participants completed questionnaires detailing MMR vaccination history and demographics. **Key Findings:** Measles seropositivity was 66.8% (268/401), mumps seropositivity was 76.3% (306/401), and combined measles and mumps seropositivity was 54.1% (217/401). Seropositivity for measles antibodies showed significant associations with age and gender. **Conclusion:** Seroprevalence levels for measles and mumps antibodies were suboptimal in this cohort of future healthcare workers. Given their heightened exposure risk, a booster vaccination strategy is recommended. Further investigation is warranted to elucidate the factors contributing to low immunity. **Recommendations:** A booster vaccination strategy is recommended.



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Introduction

Despite the implementation of broad immunization programs, measles and mumps continue to pose a considerable global burden of disease. The live-attenuated trivalent measles-mumps-rubella (MMR) vaccine achieves a reported efficacy of 97% against measles and 86% against mumps following the completion of the two-dose series (typically at 12-15 months and 4-6 years or 3 months after 1st dose) (1),(2). Nevertheless, a global reduction in measles vaccination coverage was followed in 2022 by a case increase of 18% and a mortality increase of 43%, culminating in 9 million cases and 136,000 deaths, primarily in children. This trend underscores the urgent need for targeted immunization strategies (3). Concurrently, mumps resurged globally, with numerous outbreaks reported in diverse populations (4).

Palestine's dual experience with measles and mumps reveals divergent epidemiological trajectories despite shared vaccination protocols. The evolution of Palestine's vaccination program reflects a dynamic and responsive public health strategy. Initially, measles vaccination was introduced in 1969 as a single dose at 9 months, marking an important milestone in the nation's immunization efforts. The subsequent introduction of the measles-mumps-rubella (MMR) vaccine in 1988, initially administered as a single dose at 15 months, represented a significant advancement in the program's scope and effectiveness. Between 1995 and 2009, the concurrent administration of both the standalone measles vaccine at 9 months and the MMR vaccine at 15 months demonstrated the program's adaptive approach to optimizing immunization schedules.

A pivotal development occurred in 2009 with the introduction of a second MMR dose at 18 months, further enhancing the program's robustness. By November 2011, the standalone measles vaccine was discontinued entirely, streamlining the immunization process. Today, the Palestinian National Immunization Program administers two doses of the MMR vaccine at 12 and 18 months, a schedule designed to provide early protection and ensure high coverage before children enter school (5). This strategic approach underscores the program's commitment to maintaining high immunization rates, as evidenced by the consistent MMR vaccination coverage in the West Bank, which has ranged between 92% and 100% from 2009 to 2024, according to Palestinian Ministry of Health annual reports (6) (7)

Measles demonstrates operational elimination thresholds punctuated by isolated resurgences – evidenced by only 4 cases during 2005–2016, a 2017 West Bank spike (1.42/100,000), and minimal 2023 transmission (2 cases nationally). Conversely, mumps exhibits endemic persistence with recurrent high-amplitude outbreaks: the 2003 Nablus cluster (>4,000 cases),

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2014 hyperendemicity (18,535 cases; Gaza incidence 1,053/100,000), sustained transmission during 2015-2018 (7,118 cases), and ongoing 2023 burden (170 cases; national incidence 3.29/100,000). This 20-fold higher contemporary incidence of mumps versus measles (3.29 vs 0.09/100,000 in 2023) underscores fundamental differences in vaccine durability and viral transmission dynamics. The 3.4-fold difference in mumps incidence between Gaza (5.48/100,000) and the West Bank (1.63/100,000) in 2023 is another sign of differences in immunity levels between regions. (8)

Contemporary mumps outbreaks disproportionately affect young adults (18-29 years) with documented two-dose vaccination histories, contrasting with the pre-vaccine paediatric peak (5-9 years) (1)(8) The observed epidemiological change is attributable to secondary vaccine failure, defined by waning immunity and declining humoral and memory responses, rather than primary vaccine failure [8]. Notably, the Palestinian vaccination program introduced a second dose of MMR only in 2009; consequently, our target cohort of medical and paramedical students (aged 18-23 years in 2020-2021) had received only a single dose of mumps-containing vaccine during childhood, placing them at potentially higher risk of waning immunity (5). Healthcare trainees constitute a critical surveillance group due to heightened exposure and dissemination risks during clinical activities (9). This study aims to determine the seroprevalence of measles and mumps IgG antibodies among a sample of university students between 2020 and 2021, to assess factors associated with seronegativity, and to evaluate the potential need for booster vaccination strategies in this population. The findings carry important implications for the potential need for booster vaccinations, particularly in this resource-limited context.

Materials and methods

Study design and population: A cross-sectional investigation was conducted at An-Najah University (Nablus, Palestine) between October 15, 2020, and March 15, 2021. After ethical approval (An-Najah National University IRB), medical and paramedical students (18-23 years) were enrolled following written informed consent. Exclusion criteria included immunodeficiency disorders, acute febrile illness, residence outside Palestine during ages 0-6 years, or unverified childhood measles/mumps vaccination.

Sample Size Calculation: The sample size was determined through single population proportion formula to estimate the seroprevalence of measles and mumps antibodies among medical students. Assuming a conservative prevalence estimate of 50%, a standard approach to maximize sample size, we set a 95% confidence level and a 5% margin of error. This calculation initially yielded a sample size of 385 participants. Given that the total source population consisted of 3,000 medical students, we applied a finite population correction, which adjusted the required sample size to 342 participants. To further account for potential non-response rates or attrition, estimated at 15–20%, we increased the sample size by 17%, resulting in a final target of 401 students. This adjustment ensures that our study will achieve prevalence estimates with sufficient precision and statistical power for subgroup analyses.

Data and specimen collection: A convenience sampling approach was used. Participants were recruited from various locations within the Faculty of Medicine and Health Sciences, including lecture halls, the cafeteria, and clinical skills labs. Students were invited to participate until the target sample size was reached. Consenting participants completed paper-based structured questionnaires developed by the research team documenting demographics, vaccination history, and prior disease exposure. Following questionnaire completion, venous blood (5 mL) was drawn from each subject. Blood samples were centrifuged within 2–4 hours of collection to separate serum. Serum was then aliquoted into sterile cryovials and stored at -20°C for a maximum of 3 months before analysis, with careful measures taken to avoid repeated freeze-thaw cycles that could compromise antibody integrity.

Serological testing: Serum samples were analysed for measles-specific IgG and mumps-specific IgG antibodies using commercially available NovaLisa® ELISA kits (NovaTec Immunodiagnostica) according to manufacturer specifications. Internal quality control sera provided by the manufacturer were run with each batch to ensure assay validity and consistency. The measles assay demonstrated 97.01% sensitivity (95% CI) and 100.0% specificity (95% CI), while the mumps assay showed 93.55% sensitivity (95% CI) and 95.83% specificity (95% CI). For the final analysis, all equivocal results were conservatively interpreted as seronegative; this approach was adopted to provide a more cautious estimate of population susceptibility, minimizing the risk of overestimating immunity and ensuring that individuals with borderline antibody levels were not incorrectly classified as protected.

Statistical analysis: The data was analyzed using SPSS (vXX; IBM Corp.). Descriptive statistics were calculated to provide a clear characterization of the study population, with variables presented as frequencies and percentages (Table 1). Seroprevalence rates for measles and mumps IgG antibodies were then estimated, accompanied by their respective 95% confidence intervals. To explore potential associations between categorical variables, a bivariate analysis was conducted using chi-square tests. This analysis included an assessment of the relationship between measles and mumps seropositivity (Table 3), with statistical significance defined by a p-value of less than 0.05.

To identify independent predictors of seropositivity, two separate multivariable logistic regression models were constructed. In these models, measles seropositivity and mumps seropositivity were treated as the dependent variables. The independent variables considered in the analysis included age (categorized as 18–23 years), gender, history of chronic disease, immune disorders, and the use of immune-related medications. Adjusted odds ratios (aOR) with 95% confidence intervals were subsequently calculated, and a p-value of less than 0.05 was deemed statistically significant (Table 2). It should be noted that no missing data were encountered for the key variables under investigation. Additionally, all equivocal ELISA results were classified as seronegative for the purpose of the final analysis.

Results

Participant Demographics

A total of 401 medical and paramedical students were enrolled, with a mean age of 20 years (SD = 1.6), ranging from 18 to 23 years. The cohort comprised 209 females (52.1%) and 192 males (47.9%). All participants had received the MMR vaccine as part of the regular national childhood vaccination program in Palestine. Only a minority reported chronic diseases (4.2%), immune disorders (4.0%), or the use of immune-related medications (1.0%) (Table 1).

Seroprevalence of Measles and Mumps Antibodies

The overall seropositivity for measles and mumps antibodies was 66.8% (268/401) and 76.3% (306/401), respectively. 54.1% (217/401) of participants were seropositive for both viruses.

Table 1. Measles and Mumps Seropositivity Rates by Demographic and Clinical Characteristics:

Variable	Category	Frequency (n)	Percentage (%)	Measles Seropositive (%)	Mumps Seropositive (%)
Age (years)	18	81	20.2	41 (50.6)	58 (71.6)
	19	102	25.4	71 (69.6)	85 (83.3)
	20	82	20.4	61 (74.4)	51 (62.2)
	21	53	13.2	32 (60.4)	42 (79.2)
	22	34	8.5	25 (73.5)	27 (79.4)
	23	49	12.2	38 (77.6)	43 (87.8)
Gender	Female	209	52.1	149 (71.3)	160 (76.6)
	Male	192	47.9	119 (62.0)	146 (76.0)
Chronic disease	Yes	17	4.2	10 (58.8)	12 (70.6)
	No	384	95.8	258 (67.2)	294 (76.6)
Immune disorder	Yes	16	4.0	9 (56.3)	11 (68.8)
	No	385	96	259 (67.3)	295 (76.6)
Immune-related medication	Yes	4	1.0	2(50.0)	3 (75.0)
	No	397	99.0	266 (67.0)	303 (71.6)

In the multivariable logistic regression analysis (Table 2), age was revealed as a significant independent predictor of both measles and mumps seropositivity. Compared to the reference group of 23-year-old students, those aged 18 years showed significantly lower odds of measles seropositivity (aOR = 0.30; 95% CI: 0.14–0.64; p=0.002). Similarly, 18-year-old students had lower odds of mumps seropositivity (AOR = 0.37; 95% CI: 0.16–0.84; p=0.018), as did those aged 20 years (aOR = 0.24; 95% CI: 0.10–0.57; p=0.001). No other age groups showed significant differences Gender was independently associated with measles seropositivity, with female students having higher odds than males (aOR = 1.52; 95% CI: 1.02–2.26; p=0.039). However, no significant gender difference was found for mumps seropositivity (AOR = 1.06; 95% CI: 0.70–1.61; p=0.787).

Table 2. Multivariable Logistic Regression Analysis of Factors Associated with Measles and Mumps Seropositivity Among Medical and Paramedical Students (N = 401)

Variable	Category	Measles Seropositivity		Mumps Seropositivity	
		aOR (95% CI)	p-value	aOR (95% CI)	p-value
Age (years)	18	0.30 (0.14–0.64)*	0.002*	0.37 (0.16–0.84)*	0.018*
	19	0.66 (0.32–1.37)	0.265	0.73 (0.30–1.78)	0.489
	20	0.84 (0.39–1.79)	0.647	0.24 (0.10–0.57)*	0.001*
	21	0.44 (0.19–1.00)	0.051	0.53 (0.21–1.34)	0.180
	22	0.82 (0.32–2.10)	0.680	0.55 (0.20–1.51)	0.246
	23	1.00 (Reference)	–	1.00 (Reference)	–
Gender	Female	1.52 (1.02–2.26)	0.039*	1.06 (0.70–1.61)	0.787
	Male	1.00 (Reference)	–	1.00 (Reference)	–
Chronic disease	Yes	0.68 (0.24–1.90)	0.461	0.78 (0.28–2.18)	0.635
	No	1.00 (Reference)	–	1.00 (Reference)	–
Immune disorder	Yes	0.58 (0.20–1.65)	0.307	0.52 (0.18–1.50)	0.226
	No	1.00 (Reference)	–	1.00 (Reference)	–
Immune-related medication	Yes	0.72 (0.10–5.20)	0.745	0.66 (0.09–4.78)	0.679
	No	1.00 (Reference)	–	1.00 (Reference)	–

Data are presented as adjusted odds ratios (aOR) with 95% confidence intervals (CI) and p-values. The aOR values represent the likelihood of seropositivity for each variable category compared to the reference group. An asterisk (*) indicates statistical significance ($p < 0.05$). Age group 23 years, Male gender, and "No" responses for clinical characteristics served as reference categories. N = total number of participants included in the analysis

No significant associations were found between seropositivity for measles or mumps and chronic disease, immune disorders, or the use of immune-related medications, likely due to the small sample size in these categories (all p>0.05).

Association Between Measles and Mumps Seropositivity

A significant correlation was observed between measles and mumps antibody status. Of the 217 students seropositive for both viruses, the overlap was statistically significant (p = 0.002),

suggesting co-responsiveness or shared components or mechanisms of the vaccine (Table 3).

Table 3. Cross-tabulation of measles and mumps seropositivity

	Mumps Positive	Mumps Negative	Total
Measles Positive	217	51	268
Measles Negative	89	44	133
Total	306	95	401
p-value	0.002*		

Discussion

Despite global advancements in immunization, measles and mumps continue to pose public health challenges, particularly in young adult populations. Our study identified suboptimal levels of measles and mumps IgG antibodies among medical and paramedical students aged 18 to 23 years in Palestine, with overall seropositivity rates of 66.8% and 76.3%, respectively. These figures are concerning, especially given that all participants received two documented doses of the measles and one MMR vaccine, according to the national immunization program.

The severity of measles and mumps infection was largely contained by the development of the MMR vaccine(10)(11)(12). However, despite efforts to eliminate these diseases, they continue to annually result in significant cases, outbreaks, and deaths, primarily in developing countries (3)(4)(13)(14)(15)(16). In previous studies that targeted nearly similar age groups, measles seroprevalence rates were 81.2% in South Korea, 73.2% in Thailand, 60.7% in Brazil, and 57.1% in Turkey (17)(18)(19)(20). Multiple studies observed that individuals aged 18–24 years had the lowest measles seroprevalence. Additionally, those under 30 years of age exhibited lower seropositivity compared to individuals over 30, highlighting the increased susceptibility of younger age groups to measles infection (17)(19)(21). In addition, regarding mumps, seroprevalence rates were 74% in Turkey and 71% in Kuwait. 56.4% in Luxembourg, 57.4% in Japan, and 61.8% in Austria in previous studies (20) (22)(23)(24)(25).

Our serological surveillance study has helped to identify the susceptibility rate to measles and mumps among young age groups (18–23 years old) in Palestine. The seroprevalence of measles and mumps in our study is consistent with other studies, with seropositivity of 66.8% and 76.3% for measles and mumps, respectively (20)(22). Differences between the results of these studies may be linked to differences in geographical area, vaccination programs and coverage or socioeconomic variation of the study participants that merit further investigation.

According to the CDC, one dose of MMR vaccine provided 93% and 72% immunity against measles and mumps, respectively, and two doses of MMR vaccine provided 97% and 86% immunity (2). However, although all participants in our study had received two doses of measles and one mumps vaccine according to the Palestinian national vaccine program, relatively low measles seropositivity and the lower range of the CDC average of mumps were noticed in this study, which indicates that even complete vaccination may not protect against infection and outbreaks. This may be due to a decrease in measles and mumps IgG levels with age (26)(27). However, some age groups in this study have significantly lower measles and mumps titers compared with other ages, which might be due to faulty vaccination storage, management and delivery in those corresponding years in which different conflicts had been occurring in the country.

The serological data collected in 2020–2021 demonstrate notable differences in measles and mumps antibody positivity among students aged 18 to 23, which may be partially explained by the historical context of the Second Intifada in Palestine (2000–2005). Persistent political unrest, frequent electricity cuts, movement restrictions, and widespread disruption of healthcare services marked this period. These challenges likely affected the cold chain logistics and the accessibility of vaccination services, particularly for the administration of the second MMR dose. For example, students aged 18 at the time of testing—who would have received their measles doses (9 and 15 months) in 2003 and 2004—showed the lowest measles seropositivity rate (50.6%, $p = 0.003$), raising concerns about vaccine effectiveness or delivery during that time. Similarly, the mumps positivity rate was significantly low among 20-year-olds (62.2%, $p = 0.003$), who were vaccinated during the peak years of the Intifada. In contrast, students aged 23, who received their vaccinations in 1998—before the height of the unrest—had higher seropositivity for both measles (77.6%) and mumps (87.8%, $p = 0.001$). These findings suggest a potential long-term impact of conflict-related instability on vaccination coverage and immune response, highlighting the vulnerability of immunization programs during periods of national crisis (28).

Such low anti-measles and anti-mumps positivity among medical and paramedical students may lead to outbreaks among healthcare workers in the future, which in turn may act as amplifiers. Such a possible scenario needs urgent community and governmental attention and requires more investigations to be done to determine the exact cause and treat it before it is too late.

Our study also showed that there was a significant association between anti-measles positivity and mumps positivity results, such that participants who have a positive anti-measles result tend to have a positive anti-mumps result and vice versa, which may indicate that people who receive the MMR vaccine tend to respond to both the measles and mumps components. This in turn underlines the possibility of a faulty MMR vaccine or unresponsiveness in seronegative subjects. These results may help guide health care decisions and vaccination policies.

The main limitation of this study was that it was cross-sectional in nature, addressing a narrow age group targeting only 18-23-year-olds. Finally, this study was conducted on young medical and paramedical students, which do (not) accurately represent the entire population in Palestine. Therefore, we encourage further studies to counter this limitation and include other age groups and larger samples to yield more representative results of the current measles and mumps epidemiological status in Palestine.

We believe our study contributes to the literature because it has shed light on anti-measles and anti-mumps seroprevalence in Palestine for the first time. Importantly, it provides a snapshot of the current vaccination status, achieved with vaccination programs dating approximately twenty years ago, which may serve as a preliminary reference point. Moreover, aligning with previous studies, the study showed that age and gender may affect immunity to measles and mumps (29)(30) and emphasised the potential real risk of measles and mumps outbreaks, especially among young people and medical and paramedical students. These findings reflect the a need for a re-evaluation of the current Palestinian national immunization program. Seroprevalence surveillance allows for the identification of subgroups with higher susceptibility, and the findings may be used to guide immunizations policies. We believe that the seronegativity rates observed in our study may reflect the need for action, since measles and mumps are highly transmissible and require very high immunity rates. This study raises many questions about the effectiveness of the MMR vaccine used one two doses for measles and one dose for

mumps in the prevention of measles and mumps among young persons. Furthermore, it questions the possible causes of such low seropositivity despite the satisfactory vaccination coverage in Palestine.

In conclusion, we believe that medical sciences students in general and young age groups in particular may be at risk for mumps and measles outbreaks. Although our study offers valuable data on measles and mumps IgG seroprevalence within this university cohort, its single-center scope and narrow age range constrain the extent to which these results can be extrapolated to older age groups or populations in other regions. We therefore advocate for future multicenter serosurveys that include a wider spectrum of ages and geographic settings. Such expanded investigations will be crucial both for pinpointing the drivers of suboptimal immunity and for guiding the design of targeted, evidence-based booster vaccination strategies to prevent potential outbreaks.

Declarations

Ethics approval and consent to participate

This study was conducted in accordance with the ethical principles of the Declaration of Helsinki and relevant institutional and national guidelines. Ethical approval was granted by the Institutional Review Board (IRB) of An-Najah National University (Ref: F.M Oct. 2020/17) and the Palestinian Ministry of Health. All participants provided voluntary, written informed consent following a comprehensive explanation of the study's objectives and methods.

Competing interests

The authors declare no competing interests, financial or otherwise, related to this work.

Authors' contributions

WB: Conceptualisation, Methodology, Formal Analysis, Resources, Data Curation, Writing – Original Draft, Writing – Review & Editing, Supervision, Project Administration
LQ: Methodology, Formal Analysis, Writing – Original Draft
RS: Methodology, Formal Analysis, Writing – Original Draft
AM: Methodology, Formal Analysis, Writing – Original Draft
AQ: Methodology, Formal Analysis, Writing – Original Draft
SJ: Methodology, Formal Analysis, Writing – Original Draft
HW: Data Curation, Writing – Review & Editing, Supervision
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References:

1. McLean HQ, Fiebelkorn AP, Temte JL, Wallace GS. Prevention of measles, rubella, congenital rubella syndrome, and mumps, 2013: Summary recommendations of the Advisory Committee on Immunization Practices (ACIP). MMWR Recommendations and Reports. 2013;62(1).
2. Prevention C for DC and. Measles vaccination [Internet]. Atlanta: U.S. Department of Health and Human Services [Internet]. Available from: https://www.cdc.gov/measles/vaccines/index.html
3. Organization WH. Global measles threat continues to grow as another year passes with millions of children unvaccinated [Internet]. Geneva: WHO; 2023 Nov 16 [Internet]. 2023. Available from: https://www.who.int/news/item/16-11-2023-global-measles-threat-continues-to-grow-as-another-year-passes-with-millions-of-children-unvaccinated
4. Prevention C for DC and. Mumps cases and outbreaks [Internet]. Atlanta: U.S. Department of Health and Human Services; 2023 Aug 29 [Internet]. 2023. Available from: https://www.cdc.gov/mumps/outbreaks.html
5. PMD, MoH, 2025. Preventive Medicine Department M of Health. No Title.
6. Health M of. Health Annual Report Palestine 2009. 2009.
7. Health M of. Health Annual Report Palestine 2024. 2024.
8. Health M of. Health Annual Report Palestine 2023.
9. Arunkumar G, Vandana KE, Sathiakumar N. Prevalence of measles, mumps, rubella, and varicella susceptibility among health science students in a University in India. Am J Ind Med. 2013 Jan 1;56(1):58–64. doi:https://doi.org/10.1002/ajim.22046
10. Prevention C for DC and. MMWR Morb Mortal Wkly Rep. 1994. Summary of notifiable diseases, United States, 1993.
11. Prevention C for DC and. Summary of Notifiable Diseases --- United States, 2005 [Internet]. 2007. Available from: https://www.cdc.gov/mmwr/preview/mmwrhtml/mm5453a1.htm
12. Galazka AM, Robertson SE, Kraigher A. Mumps and mumps vaccine: a global review. Bull World Health Organ. 1999;77(1):3–14. PubMed PMID: 10063655.
13. Bangor-Jones RD, Dowse GK, Giele CM, van Buynder PG, Hodge MM, Whitty MM. A prolonged mumps outbreak among highly vaccinated Aboriginal people in the Kimberley region of Western Australia. Medical Journal of Australia. 2009 Oct 1;191(7):398–401. doi:https://doi.org/10.5694/j.1326-5377.2009.tb02850.x
14. Fong SY, Mori D, John JL, Giloi N, Jeffree MS, Ahmed K. Mumps outbreak in university students: first detection of mumps virus genotype F in Borneo. Trop Med Health. 2022;50(1):20. doi:10.1186/s41182-022-00411-w
15. Rota JS, Turner JC, Yost-Daljev MK, Freeman M, Toney DM, Meisel E, et al. Investigation of a mumps outbreak among university students with two

measles–mumps–rubella (MMR) vaccinations, Virginia, September–December 2006. J Med Virol. 2009 Oct 1;81(10):1819–25. doi:https://doi.org/10.1002/jmv.21557

16. Perez Duque M, San-Bento A, Léon L, Custódio P, Esperança MA, Albuquerque MJ, et al. Mumps outbreak among fully vaccinated school-age children and young adults, Portugal 2019/2020. Epidemiol Infect. 2021/08/27. 2021;149:e205. doi:DOI: 10.1017/S0950268821002028

17. Kwak YG, Song JE, Oh GB, Jeong IH, Cho CR, Kim N, et al. Comparison of the Seroprevalence of Measles Antibodies among Healthcare Workers in Two Korean Hospitals in 2019. Infect Chemother [Internet]. 2020 Mar;52(1):93–7. Available from: https://doi.org/10.3947/ic.2020.52.1.93

19. Wanlapakorn N, Wasitthankasem R, Vichaiwattana P, Auphimai C, Yoocharoen P, Vongpunsawad S, et al. Antibodies against measles and rubella virus among different age groups in Thailand: A population-based serological survey. PLoS One. 2019;14(11):e0225606. doi:10.1371/journal.pone.0225606 PubMed PMID: 31770412.

19. Estofolete CF, Milhim BHG de A, França CCG de, Silva GCD da, Augusto MT, Terzian ACB, et al. Prevalence of Measles Antibodies in São José do Rio Preto, São Paulo, Brazil: A serological survey model. Sci Rep. 2020;10(1):5179. doi:10.1038/s41598-020-62151-3

20. Karadeniz A, Akduman Alaşehir E. Seroepidemiology of hepatitis viruses, measles, mumps, rubella and varicella among healthcare workers and students: Should we screen before vaccination? J Infect Public Health. 2020;13(4):480–4. doi:https://doi.org/10.1016/j.jiph.2020.01.309

21. Levine H, Zarka S, Ankol OE, Rozhavski V, Davidovitch N, Aboudy Y, et al. Seroprevalence of measles, mumps and rubella among young adults, after 20 years of universal 2-dose MMR vaccination in Israel. Hum Vaccin Immunother. 2015;11(6):1400–5. doi:10.1080/21645515.2015.1032489 PubMed PMID: 25891446.

22. Madi N, Altawalah H, Alfouzan W, Al-Nakib W, Al-Roumi E, Jeragh A. Assessment of immune status against measles, mumps, and rubella in young Kuwaitis: MMR vaccine efficacy. J Med Virol. 2020 Aug;92(8):963–70. doi:10.1002/jmv.25665 PubMed PMID: 31919861.

23. Hübschen JM, Charpentier E, Weicherding P, Muller CP. IgG antibody prevalence suggests high immunization needs in newcomers to Luxembourg, 2012. Vaccine. 2018 Feb;36(6):899–905. doi:10.1016/j.vaccine.2017.12.041 PubMed PMID: 29306505.

24. Kanamori H, Tokuda K, Ikeda S, Endo S, Ishizawa C, Hirai Y, et al. Prevaccination antibody screening and immunization program for healthcare personnel against measles, mumps, rubella, and varicella in a Japanese tertiary care hospital. Tohoku J Exp Med. 2014 Oct;234(2):111–6. doi:10.1620/tjem.234.111 PubMed PMID: 25224029.

25. Ringler M, Göbel G, Möst J, Weithaler K. Fully vaccinated children are rare: immunization coverage and seroprevalence in Austrian school children. Eur J Epidemiol. 2003;18(2):161–70. doi:10.1023/a:1023038705835 PubMed PMID: 12733839.

26. Castiñeiras ACP, Sales AC, Picone C de M, Diogo CL, Rossi ÁD, Galliez RM, et al. The decline of measles antibody titers in previously vaccinated adults: a cross-sectional analysis. Rev Inst Med Trop Sao Paulo. 2024;66:e4. doi:10.1590/S1678-9946202466004 PubMed PMID: 38198377.

27. Prevention C for DC and. Immunization of health-care personnel: recommendations of the Advisory Committee on Immunization Practices (ACIP). [Internet]. 2011. Available from: https://www.cdc.gov/mmwr/preview/mmwrhtml/rr6007a1.htm

28. Martini M, Valchi L, Massaro E, Parrella R, Orsini D. War and Health: the devastating impact of conflict on Wellbeing and Humanitarian Crises. J Prev Med Hyg. 2024 Sep;65(3):E464–8. doi:10.15167/2421-4248/jpmh2024.65.3.3412 PubMed PMID: 39758762.

29. Kumakura S, Shibata H, Onoda K, Nishimura N, Matsuda C, Hirose M. Seroprevalence survey on measles, mumps, rubella and varicella antibodies in healthcare workers in Japan: sex, age, occupational-related differences and vaccine efficacy. Epidemiol Infect. 2014 Jan;142(1):12–9. doi:10.1017/S0950268813000393 PubMed PMID: 23574767.

33. Klein SL, Flanagan KL. Sex differences in immune responses. Nat Rev Immunol. 2016 Oct;16(10):626–38. doi:10.1038/nri.2016.90 PubMed PMID: 27546235.